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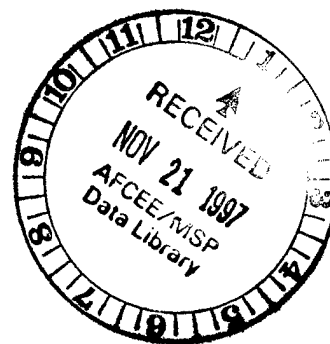
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PARSONS ENGINEERING SCIENCE, INC.

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20 November 1997



Major Ed Marchand
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, Texas 78235-5363

Subject: Extended Bioventing Testing Results for Buildings 2034/2035, Fairchild
AFB, Washington (Contract No. F41624-92-8036, Order 17)

Dear Major Marchand:

This letter presents the results of the bioventing system monitoring performed by Parsons Engineering Science, Inc. (Parsons ES) in October 1997 at Buildings 2034/2035 at Fairchild Air Force Base (AFB), Washington. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES between 1 and 3 October 1997, to assess the extent of remediation completed during 1 year of full-scale air injection bioventing. The purpose of this letter is to summarize site remediation activities to date, present the results of the October 1997 system monitoring event and compare them with the results of the earlier pilot testing events, and to recommend future remediation activities for the site based on these findings.

SITE REMEDIATION HISTORY

Building 2034 is the JP-4 fuels laboratory. An underground storage tank (UST), approximately 250 gallons in size, was located immediately east of Building 2034 for storage of waste JP-4 fuel. The UST was removed in March 1990, and the excavation was backfilled with clean, sandy fill. Building 2035 is the pumphouse for the fuel storage area. Ten 50,000-gallon USTs and one underground 2,000-gallon filter/separator tank for storage and handling of JP-4 jet fuel are associated with Building 2035. The locations of Buildings 2034 and 2035 are illustrated in Figure 1 (attached).

In October 1993, pilot-scale bioventing systems were installed at Buildings 2034 and 2035 by Parsons ES as part of the Air Force Center for Environmental Excellence (AFCEE) Bioventing Pilot Test Initiative Project. Each bioventing system consisted of one air injection vent well (VW), three soil gas monitoring points (MPs), a blower unit, and associated piping, controls, and electrical service. The initial bioventing test consisted of soil and soil gas sampling and *in situ* respiration and air permeability testing. The results from the initial bioventing tests indicated that oxygen levels within the contaminated soil zones were depleted, and that air-injection bioventing is an effective method for providing oxygen to vadose zone soils. A radius of oxygen influence of at least 33 feet was observed at each site. Further details on the pilot test

procedures and results can be found in the Interim Pilot Test Results Report (Engineering-Science, Inc. [ES], 1994).

Extended bioventing pilot tests were performed at Buildings 2034 and 2035 from March 1994 through August 1995, to determine if *in situ* bioventing would be a feasible cleanup technology for the fuel-contaminated soils within the unsaturated zone. Soil and soil gas data collected following the extended bioventing pilot tests confirmed significant contaminant removal in the test areas at both sites. Significant reductions in total volatile hydrocarbons (TVH), benzene, toluene, ethylbenzene, and xylenes (BTEX) were observed in soil gas, and significant reductions in total recoverable petroleum hydrocarbon (TRPH) and BTEX concentrations were observed in soil as a result of extended pilot-scale bioventing system operation. In addition, the extended pilot tests demonstrated that significant oxygen utilization and biodegradation were continuing at the test locations, and that continued bioventing would sustain the biodegradation.

The success of the bioventing pilot tests at these two sites supported the recommendation of an expanded (full-scale) bioventing system as the most economical approach of remediating the remaining hydrocarbon-contaminated soils in the vicinity of Buildings 2034 and 2035. In March 1995, as part of the AFCEE Extended Bioventing Project, the sites were initially funded for installation of an expanded-scale bioventing system to treat soils at both sites (Option 4) and 1 year of expanded-scale bioventing system operation, followed by soil gas sampling and respiration testing (Option 1). Additional AFCEE funding (another Option 4) was later provided so that the bioventing system could be expanded again to provide full-scale treatment of site soils.

The bioventing system at Building 2035 was expanded in two mobilizations to remediate both sites. During system-expansion activities in May 1996, three new VWs, one MP, a new blower system, and associated piping, controls, and electrical service, were installed in the vicinity of Buildings 2034 and 2035. Two groundwater monitoring wells also were installed. In August 1996, 12 additional boreholes were advanced, and 14 soil samples were collected in order to more fully define the extent of vadose zone contamination east and south of Building 2035. Based on these contaminant delineation efforts, two additional VWs and one additional MP were installed in the newly characterized portions of the site. System installation was performed by Parsons ES and subcontractors under the supervision of Parsons ES. The system was installed as described in the *Final Remedial Action Plan for Expanded Bioventing System, Buildings 2034/2035, Fairchild AFB, Washington* (Parsons ES, 1996a) and in the 19 July 1996 and 9 December 1996 letters (Parsons ES, 1996b and 1996c) from Parsons ES to AFCEE and Fairchild AFB. Figure 1 shows the site layout with the locations of the full-scale bioventing system components.

The full-scale bioventing system was started on 24 May 1996, with air injection into VW-2035-1, -2, and -3. Air injection was initiated to VW-2035-4, VW-2035-5, and VW-2035-6 on 29 August 1996. On 7 October 1996, air flow rates were increased so that approximately 21 cubic feet per minute (cfm) was being injected into each VW.

Although lower flow rates had proven sufficient during system optimization in May 1996, the flow rates were increased to compensate for higher water table elevations expected during late winter, which would result in greater system pressures and reduced air flow to each VW. In March 1997, Parsons ES visited the site to check on system operation and evaluate subsurface oxygenation of vadose zone soils.

The Option 1 soil gas sampling and *in situ* respiration testing was performed between 1 and 3 October 1997, 3.5 years after the March 1994 initiation of bioventing at Buildings 2034 and 2035. The system was shut down 1 month prior to sampling/testing to allow soils and soil gas to come to equilibrium and allow comparison with previous site conditions. The blower system was started and optimized following testing to continue bioventing treatment of site soils. Oxygen influence measurements from March 1997 and soil gas sampling and respiration testing results from the October 1997 monitoring event and are presented in this report.

OXYGEN INFLUENCE

During a site visit in March 1997, soil gas was monitored at several MPs while the pilot-scale blower system at Building 2034 and the new full-scale blower system were running to determine if hydrocarbon-contaminated soils are being adequately oxygenated, especially in the area of full-scale bioventing system air injection. Table 1 (attached) presents the results of the oxygen influence measurements and also provides baseline subsurface oxygen concentrations prior to initiation of bioventing. During March 1997 measurements, the water table was relatively high as a result of late winter/early spring precipitation, and the majority of the deeper MP screens were below the groundwater surface. The results obtained from the MPs that could be sampled indicated that oxygen was sufficiently distributed throughout the subsurface. The flow rates also were checked during this site visit and found to vary slightly among the six VWs. Prior to leaving the site, the air flow rates were balanced, with approximately 16 cfm of air being injected into each VW.

SOIL GAS CHEMISTRY RESULTS

Field screening and collection of soil gas samples for laboratory analysis were performed on 1 October 1997 following approximately 1 year of full-scale system operation and 1 month of system shutdown. The pilot-scale blower system at Building 2034 had not been in operation since early June 1997. Following full-scale system shutdown, soil gas samples were collected from each MP interval and field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and TVH.

Table 2 presents the field soil gas screening results for those MPs that have historically shown signs of significant petroleum contamination (elevated TVH and low oxygen concentrations). Table 2 also includes the initial soil gas sampling results from each MP for comparison. Throughout shallow soils (i.e., 4 and 5 feet below ground surface [bgs]) in the Building 2034/2035 area, static oxygen concentrations in soil gas were above 5 percent, with the exception of MP-2035-1-5', which had an oxygen

concentration of 1.7 percent. In deeper soils (7 to 8.5 feet bgs) in the Building 2034 area, static oxygen concentrations were at or above 4.5 percent at all sampling locations. These results indicate that aerobic hydrocarbon biodegradation rates are slow, suggesting that little substrate (i.e., fuel hydrocarbons) remains and that bioventing is no longer necessary to provide oxygen to these soils. TVH results at these locations also have decreased, further indicating the decreased extent of fuel hydrocarbons in these soils (Table 2).

Soil gas results from the deeper soils (i.e., 7.5 to 8 feet bgs) in the vicinity of Building 2035 indicate significant respiration and the continued presence of significant fuel hydrocarbon contamination. The soil gas oxygen concentrations measured at the deep MP screened intervals at MPs-2035-1 through -3, MP-2035-5, and MPE-A were at, or below, 1.0 percent. Likewise, TVH concentrations ranged from 220 to greater than 20,000 parts per million, volume per volume (ppmv). Although there have been substantial reductions in soil gas TVH concentrations, it is apparent that significant fuel contamination remains in these soils. Purging groundwater from these MPs during previous sampling events has demonstrated that these soils typically are below the groundwater surface from late winter until early summer. Therefore, these soils are not benefiting from year-round aerobic treatment.

Soil gas samples for laboratory analysis were collected from six MP screened intervals. Three samples were collected from original pilot-scale MPs (MP-2034-3-8.5', MP-2035-1-7.5', and MP-2035-3-7.5'), and three samples were collected from MPs installed during full-scale expansion of the bioventing system (MP-2035-4-5', MP-2035-5-8', and MPE-A-8'). The laboratory soil gas samples were sent to Air Toxics, Ltd. in Folsom, California and analyzed for TVH and BTEX by US Environmental Protection Agency (USEPA) Method TO-3. Laboratory soil gas sampling results for all samples collected since the inception of bioventing activities at the site are presented in Table 3. Again, the results indicate that petroleum hydrocarbons have decreased significantly in the shallow soils throughout the Building 2034/2035 area and in the deeper soils near Building 2034. The results also indicate that hydrocarbon contamination remains in deep soils in the vicinity of Building 2035; however, significant decreases in TVH and BTEX soil gas concentrations have occurred in this area as well.

Residual fuel hydrocarbons in site soils have been significantly reduced, as indicated by the soil gas sampling results. However, it appears that smear-zone contamination remains in soils near the water table in the vicinity of Building 2035. While soil gas concentrations of TVH and BTEX have decreased significantly in these soils, sufficient hydrocarbon contamination is still present to result in anaerobic soil gas conditions without the application of bioventing.

RESPIRATION TEST RESULTS

During the October 1997 site visit, *in situ* respiration testing was performed. An area respiration test was performed according to AFCEE technical protocol procedures

(Hinchee *et al.*, 1992). After collection of soil gas samples under static conditions, the full-scale system blower was started and allowed to run for 20 hours to provide oxygen to the subsurface soils. The area respiration test was initiated by shutting down the blower and measuring changes in oxygen, carbon dioxide, and TVH soil gas concentrations over a 30-hour period. Soil gas measurements were recorded at all MPs that exhibited static oxygen concentrations of less than 5 percent (MP-2034-3-8.5', MP-2035-1-5', MP-2035-1-7.5', MP-2035-2-7.5', MP-2035-3-7.5', MP-2035-5-8', and MPE-A-8'). For those points where appreciable respiration was observed, oxygen utilization and aerobic fuel biodegradation rates were calculated. These rates are shown in Table 4 along with the results of the initial, 14-month, and 17-month respiration tests.

Oxygen utilization rates and biodegradation rates could not be calculated for MP-2035-1-5' and MP-2035-1-7.5' because these intervals were not sufficiently oxygenated during the 20-hour injection period. Although MP-2035-1 is only 10 feet from VW-2035-1, tight soils around this MP make collection of soil gas samples very difficult and result in slower oxygen response after air injection has been initiated. The oxygen concentration at MP-2035-2-7.5' rose to 17 percent during the 20-hour air injection period; however, no oxygen utilization was observed at this MP.

Moderate oxygen utilization rates were observed at the remaining monitoring points. For the two MPs that had been previously tested during the 17-month testing event (MP-2034-3-8.5' and MP-2035-3-7.5'), the oxygen utilization rates and biodegradation rates have remained relatively constant. These results and the moderate rates observed at the other monitoring points suggest that significant levels of fuel hydrocarbons still remain below 7 feet bgs; however, bioventing continues to enhance aerobic biodegradation when these soils are not saturated. Seasonal groundwater fluctuations at the site have created a smear zone where fuel hydrocarbons dissolved in groundwater are smeared through these soils with water table movement, resulting in sustained rates of biodegradation.

CONCLUSIONS AND RECOMMENDATIONS

Parsons ES recommends that Fairchild AFB continue to operate the full-scale bioventing system blower at Building 2035 for an additional year to further reduce fuel hydrocarbons present in the deeper soils in the site vicinity. Sustained bioventing system operation will continue to oxygenate these smear-zone soils. It is recommended that oxygen influence be measured and air injection flow rates be checked, and adjusted if necessary, after approximately 6 months to ensure even distribution of air flow. At the end of the additional year of system operation, another respiration testing/soil gas sampling event should be performed. If these results are favorable (i.e., if respiration rates and soil gas BTEX and TVH concentrations have decreased significantly, and if static oxygen concentrations are above 5 percent), it is recommended that a risk-based closure be pursued.

In September 1997, Parsons ES was notified by Fairchild AFB personnel that the pilot-scale blower system installed at Building 2034 in October 1993 had not been in operation since 8 June 1997. Because soils in the vicinity of VW-2034-1 were aerobic after nearly 4 months without air injection bioventing (Tables 2 and 3), it is recommended that the Building 2034 blower system remain off and not be repaired and restarted. The full-scale blower system was restarted on 3 October 1997, following completion of respiration testing.

This report is the final deliverable relating to the Building 2034/2035 site under the AFCEE Extended Bioventing Project. If you have any questions or require additional information, please contact either Brian Blicher at (406) 586-7899, or John Ratz at (303) 831-8100.

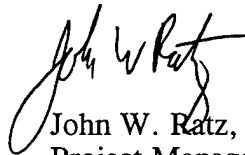
Sincerely,

PARSONS ENGINEERING SCIENCE, INC.



Craig B. Snyder
for

Brian R. Blicher, P.E.
Site Manager



John W. Ratz

John W. Ratz, P.E.
Project Manager

Attachments:

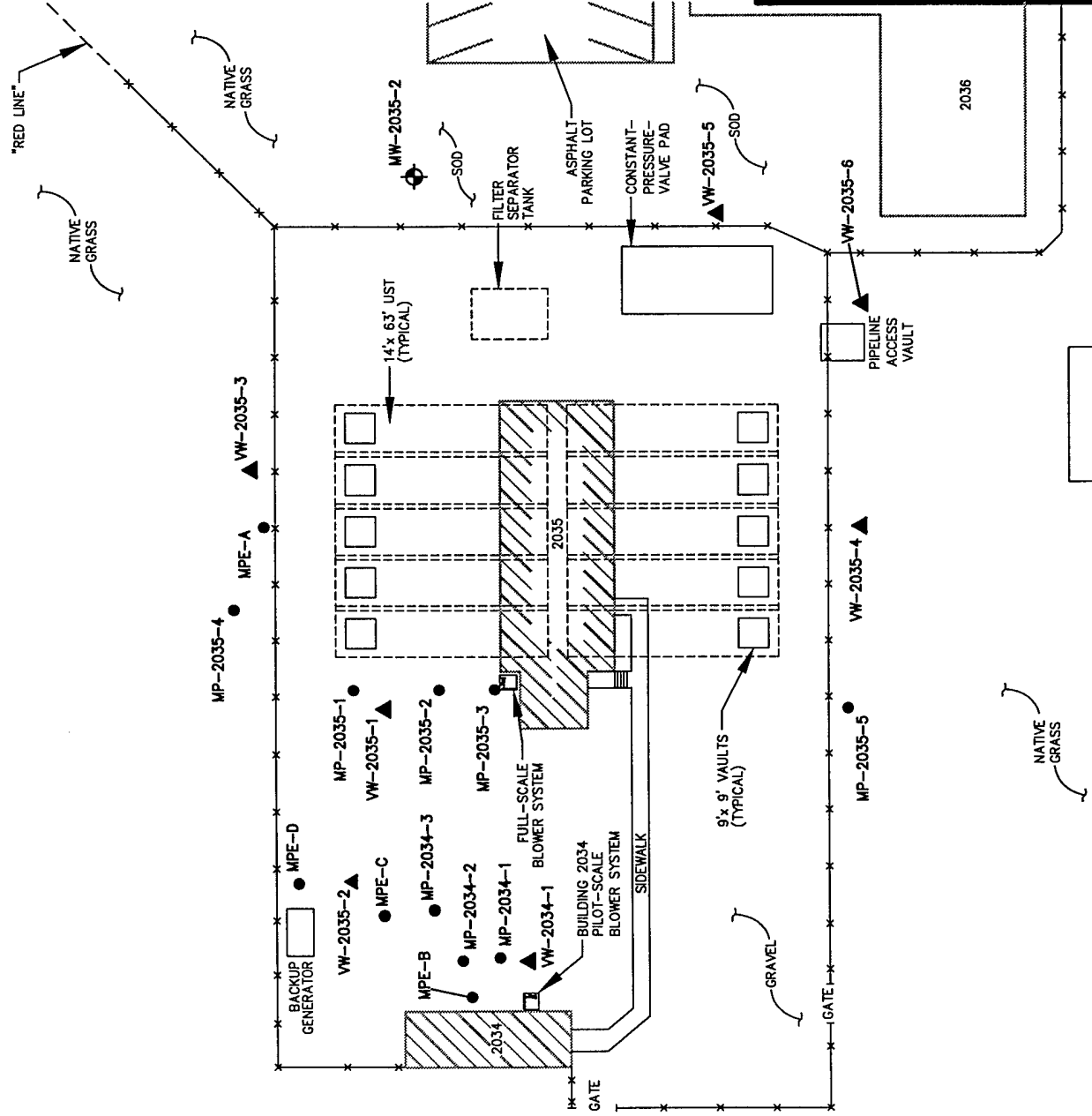
Figure 1, Tables 1 through 4

cc: Bruce Oshita, 92 CES/CEVR, Fairchild AFB
File 727876.40110.E Letter Results Report

REFERENCES

- Engineering Science, Inc. (ES) 1994. *Part I Bioventing Pilot Test Work Plan and Part II, Draft Interim Bioventing Pilot Test Results Report for PS-2, PS-1A, PS-1B, Building 2034, and Building 2035. Fairchild Air Force Base, Washington.* June.
- Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Denver, Colorado. May.
- Parsons Engineering Science, Inc. (Parsons ES) 1996a. *Final Remedial Action Plan for Expanded Bioventing System, Buildings 2034/2035, Fairchild Air Force Base, Washington.* April.
- Parsons ES. 1996b. Letter to Captain Marchand, AFCEE/ERT, regarding the Operation and Maintenance Manual, Interim Record Drawings, Summary of Initial Results, and Proposed Future Actions for Full-Scale Bioventing at Buildings 2034/2035, Fairchild Air Force Base, Washington. 19 July.
- Parsons ES 1996c. Letter to Captain Marchand, AFCEE/ERT, regarding the Record Drawings and Description of Full-Scale Bioventing System Installation at Building 2034 and 2035, Fairchild Air Force Base, Washington. 9 December.

MW-2035-1



LEGEND

MW-2035-2 GROUNDWATER MONITORING WELL

MPE-A SOIL GAS MONITORING POINT

VW-2034-1 AIR INJECTION VENT WELL

FIGURE 1

SITE LAYOUT

Buildings 2034/2035
Fairchild Air Force Base, Washington

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

TABLE 1
OXYGEN INFLUENCE
BUILDINGS 2034/2035
FAIRCHILD AIR FORCE BASE, WASHINGTON

Sample Location	Screen Depth (feet)	Distance to Nearest Vent Well (feet)	Nearest Vent Well	Prior to air injection		During air injection ^{a/}	
				Oxygen (percent)	Carbon Dioxide (percent)	Oxygen (percent)	Carbon Dioxide (percent)
MP-2034-2	4	20	VW-2034-1	11.9 ^{b/}	5.3	20.1	0.6
MP-2034-2	7	20	VW-2034-1	8.4 ^{b/}	2.2	20.3	0.2
MP-2034-3	5	26	VW-2035-2	18.4 ^{b/}	1.0	20.7	0.1
MP-2034-3	8.5	26	VW-2035-2	17.9 ^{b/}	1.4	20.8	0.1
MP-2035-1	5	10	VW-2035-1	10.2 ^{c/}	4.9	NM ^{d/}	NM
MP-2035-1	7.5	10	VW-2035-1	1.6 ^{b/}	6.0	NM	NM
MP-2035-2	5	16	VW-2035-1	16.9 ^{b/}	2.7	15.3	1.7
MP-2035-2	7.5	16	VW-2035-1	0.0 ^{c/}	10.7	NM	NM
MP-2035-3	5	33	VW-2035-1	12.4 ^{b/}	1.2	20.3	0.4
MP-2035-3	7.5	33	VW-2035-1	0.0 ^{c/}	13.0	NM	NM
MP-2035-4	5	46	VW-2035-3	16.8 ^{b/}	0.3	20.3	0.4
MP-2035-5	4	41	VW-2035-4	16.5 ^{c/}	0.5	16.5	2.2
MP-2035-5	8	41	VW-2035-4	0.0 ^{c/}	15.6	NM	NM
MPE-A	4	17	VW-2035-3	15.0 ^{b/}	4.5	20.6	0.1
MPE-A	8	17	VW-2035-3	0.0 ^{b/}	11.0	19.0	1.8

^{a/} Measured on March 27, 1997.

^{b/} Measured on May 24, 1996.

^{c/} Measured in October 1993. The monitoring point was flooded in May 1996; a soil gas sample could not be collected.

^{d/} NM = Not measured. The monitoring point was flooded; a soil gas sample could not be collected.

^{e/} Measured on August 29, 1996.

TABLE 2
SOIL GAS FIELD SCREENING RESULTS
BUILDINGS 2034/2035
FAIRCHILD AFB, WASHINGTON

Sample Location	Sample Depth (ft bgs) ^{a/}	Sampling Event	Oxygen (percent)	Carbon Dioxide (percent)	TVH ^{b/} (ppmv) ^{c/}
MP-2034-1	4	Oct-93	5.4	7.6	>10,000
		Oct-97	7.4	7.5	64
	7	Oct-93	1.0	10.2	>10,000
		Oct-97	8.3	6.1	58
MP-2034-2	4	Oct-93	8.0	7.5	1,100
		Oct-97	7.3	5.0	58
	7	Oct-93	1.9	10.6	>10,000
		Oct-97	11.2	3.9	53
MP-2034-3	5	Oct-93	11.4	5.2	280
		Oct-97	7.0	2.2	72
	8.5	Oct-93	1.4	12.5	150
		Oct-97	4.5	3.2	70
MP-2035-1	5	Oct-93	10.2	4.9	2,800
		Oct-97	1.7	6.8	116
	7.5	Oct-93	10.5	5.1	>10,000
		Oct-97	0.0	12.1	>20,000
MP-2035-2	5	Oct-93	6.9	9.0	880
		Oct-97	8.7	3.3	66
	7.5	Oct-93	0.0	10.7	6,600
		Oct-97	1.0	5.3	780
MP-2035-3	5	Oct-93	6.5	9.0	750
		Oct-97	5.9	7.1	84
	7.5	Oct-93	0.0	13.0	>10,000
		Oct-97	0.0	10.8	320
MP-2035-4	5	May-96	16.8	0.3	1,500
		Oct-97	10.9	4.4	37
MP-2035-5	8	Aug-96	0.0	15.6	>4,000
		Oct-97	0.0	11.0	220
MPE-A	8	May-96	0.0	11.0	2,200
		Oct-97	0.0	14.9	500

^{a/} ft bgs = feet below ground surface.

^{b/} TVH = total volatile hydrocarbons.

^{c/} ppmv = parts per million, volume per volume.

TABLE 3
SOIL GAS LABORATORY ANALYTICAL RESULTS
BUILDINGS 2034/2035
FAIRCHILD AFB, WASHINGTON

Sample Location	Sample Depth (ft bgs) ^{b/}	Sampling Event	Laboratory Analytical Data ^{a/}				
			TVH (ppmv) ^{c/}	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW-2034-1	5-8	Oct-93	23,000	<1.1 ^{d/}	<1.1	18	120
		Aug-95	0.52	<0.002	<0.002	<0.002	0.006
MP-2034-1	7	Oct-93	29,000	32	100	27	140
		Aug-95	6.4	<0.002	<0.002	<0.002	<0.002
MP-2034-3	8.5	Oct-93	570	<0.55	2.1	1.5	8
		Aug-95	260	0.048	0.6	0.88	4.9
		Oct-97	21	0.015	0.010	0.028	0.085
VW-2035-1	5-8	Oct-93	17,000	<1.0	<1.0	28	51
		Aug-95	110	0.48	0.64	0.23	0.28
MP-2035-1	7.5	Oct-93	14,000	<1.0	<1.0	37	58
		Aug-95	1,700	4.7	6.0	1.9	17
		May-96	2,000	5.4	8.3	5.2	13
		Oct-97	5,900	1.6	5.9	6.1	14
MP-2035-3	7.5	Oct-93	14,000	<1.0	68	23	150
		Aug-95	1,200	3.5	13	5.5	13
		Oct-97	470	0.23	1.4	1.4 ^{e/}	5.6 ^{e/}
MP-2035-4	5	May-96	2,100	5.0	13	12	56
		Oct-97	16	0.011	0.012	0.037	0.098
MP-2035-5	8	Aug-96	5,700	7.0	7.7	6.8	34
		Oct-97	400	0.30	1.9	0.63	1.4
MPE-A	8	May-96	21,000	55	130	42	76
		Oct-97	130	1.6	1.5	1.4	4.2

^{a/} Laboratory analysis of soil gas performed using USEPA Method TO-3.

Laboratory TVH referenced to jet fuel (molecular weight=156).

^{b/} ft bgs = feet below ground surface.

^{c/} ppmv = parts per million, volume per volume. TVH = total volatile hydrocarbons.

^{d/} < = less than the laboratory reporting limit shown.

^{e/} Laboratory-reported value may be biased due to apparent matrix interferences.

TABLE 4
RESPIRATION AND DEGRADATION RATES
BUILDINGS 2034/2035
FAIRCHILD AFB, WASHINGTON

Location-Depth	Initial ^{a/}		14-Month ^{a/}		17-Month ^{a/}		3 1/2-Year ^{a/}	
	Respiration Rate (% O ₂ /hr) ^{b/}	Degradation Rate (mg/kg/year) ^{d/}	Soil Temperature (°C)	Respiration Rate (% O ₂ /hr)	Degradation Rate ^{d/} (mg/kg/year)	Respiration Rate (% O ₂ /hr)	Degradation Rate ^{d/} (mg/kg/year)	Soil Temperature (°C)
Building 2034								
VW1 (5'-10')	0.78	2,500	NM ^{e/}	NM	NC ^{e/}	0.05	170	NM
MP1-4	0.96	2,900	12	0.45	1,400	1.26	3,800	15.5
MP1-7	0.72	2,700	14	0.08	260	0.17	640	15.4
MP2-4	0.50	1,600	NM	NC ^{b/}	NC	0.11	340	NM
MP2-7	1.08	2,100	NM	0.19	480	0.29	550	NM
MP3-5	0.12	380	NM	0.003	10	0.02	70	NM
MP3-8.5	0.46	2,000	NM	NC ^{d/}	NC	0.06	180	NM
Building 2035								
VW1 (5'-10')	0.39	1,700	NM	NM	NC	0.06	360	NM
MP1-5	0.22	690	14.3	NM ^{d/}	NC	0.31	990	17.0
MP1-7.5	0.23	750	14.6	NC ^{b/}	NC	0.52	830	16.4
MP2-5	0.11	350	NM	NC ^{d/}	NC	0.02	60	NM
MP2-7.5	0.55	1,400	NM	NM ^{d/}	NC	0.13	390	NM
MP3-5	0.35	1,100	NM	0.06	190	0.13	420	NM
MP3-7.5	0.72	3,200	NM	NM ^{d/}	NC	1.32	6,100	NM
MP5-8	NA ^{d/}	NA	NA	NA	NA	NA	NA	NM
MPE-A-8	NA	NA	NA	NA	NA	NA	NA	NM

^{a/} All *in situ* respiration tests were performed as area tests by running the blower system to provide oxygen to the entire soil profile.

^{b/} % O₂/hr = percent oxygen per hour.

^{c/} mg/kg/yr = milligrams of hydrocarbons per kilogram of soil per year.

^{d/} Degradation rates calculated assuming moisture content of the soil is average of initial and 17-month moistures.

^{e/} Degradation rates calculated assuming moisture content of the soil is same as initial moistures.

^{f/} NM = not measured.

^{g/} NC = not calculated.

^{h/} Monitoring point was not sufficiently aerated during testing event.

^{i/} Oxygen utilization was not observed at this location during the 14-month testing event.

^{j/} Monitoring point was flooded during 14-month testing event.

^{k/} Respiration test readings suspect.

^{l/} NA = not applicable; monitoring point not installed until the 1996 full-scale bioventing system expansion.